

Banggai cardinalfish (*Pterapogon kauderni*) 2015-2021

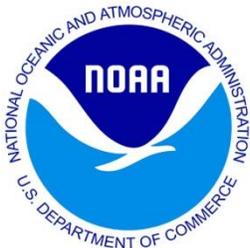
Bibliography

Claire Myers, Librarian, NOAA Central Library

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Background & Scope

The Banggai cardinalfish is a small marine bony fish. The species is endemic to the Banggai Archipelago in Indonesia but has been introduced outside of its natural range through the ornamental live reef trade. The main threats to the Banggai cardinalfish are harvest for the ornamental live reef trade and habitat destruction. In 2016, NOAA Fisheries listed the species as threatened under the Endangered Species Act.

This bibliography was developed in support of the 2021 5-year review and focuses on any relevant literature related to Banggai cardinalfish. It is intended as a reference resource for ESA staff in their work to compile and summarize any relevant new information. It is organized into four sections: Biology, Ecology, Population, and Threats.

Section I – Biology

Section one is intended to provide an overview of the life history of the Banggai cardinalfish. The research in this area includes a compilation of diet, lifespan and habitat, migration patterns, behavior, feeding, and reproduction as well as any current literature on Banggai cardinalfish biology.

Section II – Ecology

Section two is intended to provide an overview of how the Banggai cardinalfish interacts with the environment. The research in this area includes a compilation of feeding ecology, social ecology, food resources, prey composition and how climate change affects the Banggai cardinalfish.

Section III – Population

Section three is intended to provide an overview of the latest population estimates and trends for the Banggai cardinalfish.

Section IV – Threats

Section four is intended to provide an overview of threats that could represent an impediment to a species' recovery. Threats may include habitat destruction, disease, and climate change, etc. Due to popularity of this species in the aquarium trade, information regarding commercial harvest and captive breeding were also considered within the scope of threats.

Sources Reviewed

The following sources were reviewed: Biodiversity Heritage Library, BioOne Complete, Dimensions, JSTOR, Lens.org, ProQuest Earth, Atmospheric, and Aquatic Science Collection, ProQuest Ebook Central, ScienceDirect, Science.gov, Taylor & Francis Online, Web of Science, Wiley Online Library Ebooks, WorldCat, the NOAA Institutional Repository, the NOAA Central Library Catalog, Center for Biological Diversity, Animal Welfare Institute, and CITES.

Section I: Biology

Andayani, A., Astriana, B. H., & Nurliah, N. (2018). The Effect of Different Stocking Density on Survival and Growth of Cardinal Fish (Bcf) (*Pteropogon kaurdeni*) in Controlled Tank. *Jurnal Perikanan Unram*, 8(2), 43-49. <https://doi.org/10.29303/jp.v8i2.86>

Research objective was to determine the effect of different stocking densities on survival and growth of Banggai Cardinal Fish (BCF) (*Pteropogon kaurdeni*) in controlled containers. The study used an experimental method with a completely randomized design consisting of three treatment densities namely treatment A 0.833 ind / l, treatment B 1.667 ind / l, and treatment C 2.5 ind / l. Each treatment was repeated four times. The result shows that the different stocking densities effect significantly to the survival rate and daily growth rate of BCF, but do not effect significantly to the growth and length gain of BCF. The survival rate of BCF in treatment A gives the highest result (80%) and be followed by treatment B (78%) and treatment C (54%). In addition, the highest daily growth rate of BCF is found in treatment B (0,689%) and this is followed by treatment C (0,614%) and A (0,608%).

Hulu, H. D., Julyantoro, P. G. S., & Kasa, I. W. (2020). Natural Feed Selection for Supporting the Rearing of Banggai Cardinal Fish (*Pterapogon Kauderni*) in Lini Aquaculture Training Center (Latc) Bali. *Metamorfosa: Journal of Biological Sciences*, 7(1), 1. <https://doi.org/10.24843/metamorfosa.2020.v07.i01.p01>

Banggai Cardinal Fish (*Pterapogon kauderni*) are endemic ornamental fish that live in shallow waters of Banggai Island, Central Indonesia. This type of fish, including endangered fish and not many people know how to cultivate it. This research was aimed to obtain the kind of proper natural food and the optimum dose of feeding in order to support the rearing of banggai cardinal fish breeding. This research used completely randomized design and was conducted during September to December 2016. The kinds of natural food examined were trash fish, abalone (*Haliotis glabra*), and squid (*Loligo pealei*). After we found the most preferable food, the examination upon its dose was conducted under 10%, 20% and 30% of the fish weight. The 45 fish sampel have average length and weight of 3 cm and 0,47 g, respectively. Fish were reared in aquarium 95 cm x 45 cm x 35 cm. The foods were given three times a day. The research results show that abalone was mostly consumed compared to other two foods about 0,11 g/fish a day. The result of examining dose showed that the highest rate of fish growth was found under the dose of 30% which resulted 2,07 cm in length, 0,34 g in weight and the dose of 20% which resulted 2,07 cm in length, 0,33 g in weight. The statistical test result showed that the treatment under the dose of 30% and 20% was not significantly different ($P > 0,05$). Base on this study, it can be concluded that abalone is the proper natural food that supports the rearing of banggai cardinal fish with optimum dose of 20 % of fish weight per day.

Kasiroek, W., Indananda, C., Pinthong, K., Supiwong, W., Pengseng, P., & Tanomtong, A. (2017). Nor Polymorphism and Chromosome Analysis of Banggai Cardinalfish, *Pterapogon Kauderni* (Perciformes, Apogonidae). *Cytologia*, 82(1), 17-23. <https://doi.org/10.1508/cytologia.82.17>

This is the first nucleolar organizer region (NOR) polymorphism and chromosome analysis of Banggai cardinalfish (*Pterapogon kauderni* Koumans, 1933). Kidney cell samples were taken from 10 male and 10 female fish. Mitotic chromosome preparations were prepared directly from kidney cells. Conventional and Ag-NOR banding techniques were applied to stain the chromosomes. The results showed that the

diploid chromosome number of *P. kauderni* was $2n=46$, and the fundamental number (NF) was 92 in both males and females. The types of chromosomes were 6 large acrocentric, 4 medium metacentric, 14 medium submetacentric, and 22 medium acrocentric chromosomes. The results indicated that the short arm subtelomeric of the acrocentric chromosome pair 13 showed clearly observable NORs. This finding exhibited that three NOR polymorphism patterns were found: 1) homomorphic which shows an equal size of both chromosome pair 13 (13a13a), 2) heteromorphic that displays different sizes of NORs of chromosome pair 13 (13a13c) and 3) heteromorphic which is found in only one homologous chromosome pair 13 (13a13b). There was no observation of strange size chromosomes related to sex. The karyotype formula for *P. kauderni* was: $2n$ (diploid) $46 = L-6(a) + M-4(m) + M-14(sm) + M-22(a)$

Kishida, C., Watanabe, Y., Hotta, K., Minowa, Y., & Kita, J. (2015). Investigation of the Acute Toxicity Test Using the Marine Fish *Pterapogon Kauderni*. [Kaisan gyo *Pterapogon kauderni* wo mochiita kyusei dokusei shiken hou no kentou]. *Report of Marine Ecology Research Institute*(20), 17-31. Retrieved from http://www.kaiseiken.or.jp/publish/reports/lib/2015_20_02.pdf

This study investigated whether the marine fish Banggai cardinalfish *Pterapogon kauderni* is suitable as a test organism. We carried out 96 hour acute toxicity tests of chromium (Cr(VI)), tributyltin compounds (TBT) and gamma -hexachlorocyclohexane (gamma -HCH) using *P. kauderni*. Median lethal concentrations (LC sub(50)) for 96 hour exposures (Cr(VI)) 13 mg/L, TBT 2.5 μ g/L, gamma -HCH 28 μ g/L were compared with values obtained from existing toxicity data for acute tests using other fish species. Toxicity values obtained in this investigation are equal to or lower than those obtained from existing data. The results indicate that the sensitivity for toxic chemicals of *P. kauderni* is equal to or higher than those of other fish species. Considering that *P. kauderni* is easy to breed in addition to the results mentioned above, *P. kauderni* can be useful marine fish for toxicity testing.

Lempoy, R., Rondonuwu, A. B., & Bataragoa, N. E. (2020). Size, Length-Weight Relationship and Condition Factor of Banggai Cardinal Fish, *Pterapogon Kauderni* Koumans, 1933 in Lembeh Strait North Sulawesi. *JURNAL ILMIAH PLATAX*, 8(1), 30-36. <https://doi.org/10.35800/jip.8.1.2020.27599>

This study aims to determine the size distribution and the relationship between length and weight and condition factors of Banggai Cardinalfish (*Pterapogon kauderni*) in the Lembeh Strait. Fish samples were obtained by using Chang Net in the Lembeh Strait. Total fish caught were 150 individuals from three sites namely Serena Besar Island, the waters in front of LIPI and the waters in front of Papisungan village with 50 fish each. The size distribution of *Pterapogon kauderni* fish ranges from 4.13 - 8.92 cm and dominated by the size class of 7.13 - 7.72 cm while the size class of 4.13 - 4.72 cm only contains 3 individuals. The length-weight relationship of male fish is $W = 0.0285 L^2.6496$ ($n = 77$; $R^2 = 0.7231$), and female fish $W = 0.837 L^2.0723$ ($n = 73$; $R^2 = 0.6626$). The growth pattern analysis shows a negative allometric pattern both for males and females while the condition factors of male fish are 1.020 ± 0.202 and female 1.027 ± 0.236 .

Pietoyo, A. (2016). Reproductive Cycle and Weight Gonads Banggai Cardinal (*Pterapogon Kauderni*, Koumans 1933) at Different Levels of Salinity. *Samakia: Jurnal Ilmu Perikanan*, 7, 85-88. <https://doi.org/10.5281/jsapi.v7i2.308>

The purpose of this study to determine the reproductive cycle and gonad weight Banggai Cardinal in salinity treatment. Water quality measurements carried out on a daily basis to maintain water quality. Measurement of water quality, suitability for maintenance Banggai Cardinal. The reproductive cycle is not significantly different at the various treatments. 27 ppt salinity treatment is the treatment that has received positive responses to the gonad weight Banggai Cardinal ($0.0018 \pm 0.0498\%$).

Pietoyo, A., Andayani, S., & Suprijanto, A. (2016). Latent and Eggs Production of Banggai Cardinal (*Pterapogon Kauderni*, Koumans 1933) on Various Salinity Levels: Conservation Efforts. *Journal of Experimental Life Sciences*, 6(1), 16-18. <https://doi.org/10.21776/ub.jels.2016.006.01.05>

The aim of this study is to determine the best salinity level on latent and eggs production of Banggai Cardinal (*Pterapogon kauderni* Koumans 1993) based on first brood and brood production of Banggai Cardinal in the treatment. Water quality measurement was carried out every day to maintain water quality. Water quality measurement showed suitable salinity for Banggai Cardinal breeding. Brood latent showed no significant difference between the treatments. Total of 27 ppt is the level of salinity for Banggai Cardinal reproduction to gain positive respond on eggs production (42.3333 ± 7 eggs).

Pompon, N., Ndobe, S., Mansyur, K., & Tis'in, M. (2019). *Growth and Survival of Juvenile Banggai Cardinalfish (Pterapogon Kauderni) Reared under Different Salinities in Recirculating Aquaria Equipped with Protein Skimmers*. Paper presented at the IOP Conference Series: Earth and Environmental Science. <https://ui.adsabs.harvard.edu/abs/2019E&ES..253a2002P>

The Banggai cardinalfish (*Pterapogon kauderni*) is a small marine ornamental fish endemic to the Banggai Archipelago in Indonesia, listed as Endangered in the IUCN (International Union for the Conservation of Nature) Red List, and twice proposed for CITES (Convention on International Trade in Endangered Wild Species of Fauna and Flora) Appendix II listing. In addition to in-situ conservation, the Indonesian Action Plan (2017-2021) calls for ex-situ *P. kauderni* conservation, including the development of captive breeding. The accumulation of metabolic waste was suspected as a causal factor in high levels of mortality under all treatments in preliminary captive rearing trials. Protein skimmers can minimise the accumulation of potentially toxic nutrients, organic compounds, and pathogens. This research evaluated the effect of salinity on the growth and survival of juvenile *P. kauderni* in recirculating systems equipped with protein skimmers and periodical siphoning of waste with partial water change. Juvenile *P. kauderni* were obtained from the introduced population at Mamboro, Palu Bay, Central Sulawesi Province, Indonesia. Initial size range was 1-3 cm standard length (SL) and 0.105-0.329 g weight. Four salinity treatments (27 ppt, 30 ppt, 33 ppt, 36 ppt) with 5 replicates were applied, with 3 fish per experimental unit (aquarium, 20x30x20 cm, 7 litre capacity). Each fish was measured and weighed at the beginning and end of the 30 day experimental period. The fish were fed with mosquito (*Culex* sp.) larvae twice a day. The protein skimmers maintained high water quality and survival was high under all treatments, Survival was 100% at 27 ppt and 30 ppt. The 27 ppt treatment yielded the highest average growth (0.35 g in weight and 1.15 cm in SL). Our results show that juvenile *P. kauderni* grow faster at salinity levels lower than the average in endemic or introduced habitats of this species, and indicate that the use of protein skimmers can effective in promoting the survival of captive juvenile *P. kauderni*.

Prihatiningsih, P., & Hartati, S. T. (2016). Biology of Reproduction and Feeding Habit of Banggai Cardinal Fish (*Pterapogon Kauderni*, Koumans 1933) in the Banggai Island Waters. *Bawal : Widya Riset Perikanan Tangkap*, 4, 1-8. <https://doi.org/10.15578/bawal.4.1.2012.1-8>

Banggai Cardinal Fish are endemic fish obtained in the Banggai Island waters and it is currently intense fishing pressure. This study aims to determine the biological aspects of reproduction as the basis for its management. Samples obtained by using "bundre" (scoop net) during April 2010 - January 2011. The results showed that the individual length of Banggai Cardinal ranged from 1,2 cm to 7,9 cm (mean 4,0 cm) and individual weight ranged from 0,1 gram to 12,9 grams. It is allometrik growth and the average length at first captured (Lc) = 3,75 cm and smaller than average length at first maturity (Lm) = 4,40 cm. Gonadal maturity stages spread in stage I – spent, spawning takes place throughout the year and it seems total spawning, a fecundity is estimated between 12-124 eggs. The average diameter of the mature eggs ranged from 0,4 mm to 4,0 mm (the batch average of 3,02 mm). Based on food habit analysis it can be concluded that the Banggai Cardinal Fish was carnivor.

Rahman, S. A., Athirah, A., & Asaf, d. R. (2018). Concentration Dilution Salinity Towards the Ability of Fish Taken from Capungan Osmoregulasi. *Jurnal SAINTEK Peternakan dan Perikanan*. <https://doi.org/10.31227/osf.io/zse83>

One of the aspects that are very important to fish osmoregulasi process is examined capungan banggai freshwater against the media. This research aims to know the capabilities of the osmoregulasi fish capungan banggai (*p. kauderni*) against the dilution media differently to salinity. Research conducted in May to July 2016, as test animals namely fish taken from capungan with the size of the length of the range is 3.5-6 cm 3-5 g obtained from the catch area of coral reefs around the Banggai Regency waters The Islands. The experimental design used was Complete Random Design (RAL) with three treatment. The parameters observed aitu osmoregulasi ability, survival and parameters of water quality. Data were analyzed with the analysis range (ANOVA) and experimental design so that if there is a noticeable influence from each treatment, then it will continue on with test BNT. The results showed a third treatments decreased salinity capungan fish organ damage kidneys and gills on the fifth week, and was able to do osmoregulasi, that survive on water conditions 5 ppt.

Rondonuwu, A. B., Lumingas, L. J. L., Bataragoa, N. E., Pratasik, S. B., Tilaar, F. F., & Salaki, M. S. (2020). Mitochondrial Co1 Sequences of Banggai Cardinal Fish (BCf) from Lembeh Strait, North Sulawesi, Indonesia. *Aquaculture, Aquarium, Conservation & Legislation*, 13(2), 760-767. Retrieved from <https://search.proquest.com/scholarly-journals/mitochondrial-co1-sequences-banggai-cardinal-fish/docview/2394932710/se-2?accountid=28258>

This study determines the genetic structure of Banggai cardinal fish (BCF) from Lembeh Strait, North Sulawesi, based on the mitochondrial CO1 genetic marker. Sample collection used SCUBA gear and "chang net" fishing gear. One BCF specimen was collected in this study. Polymerase chain reaction (PCR) was performed using 5X Firepol PCR Master Mix. Bi-directional sequencing was done by First Base CO (Malaysia) using Big Dye© terminator chemistry (Perkin Elmer). PCR outcomes were separated using 0.8% agarose gel electrophoresis and shown by amplification of 718 bp band. The fish population found in the Lembeh Strait was *Pterapogon kauderni* Koumans, 1933 based on BLAST method. The lowest pairwise distance (d) was 0.000 (0%) and the highest was 0.324 (32.413%) with an average distance of 0.087±0.117 (8.692±11.746%). Genetic distance (d) of the ingroup was

shorter than that of the outgroup. Based on the phylogenetic tree, the population of *P. cauderni* (ingroup) forms one cluster and is separated from other fish groups (outgroup). The closest population to *P. kauderni* is *Sphaeramia nematoptera*.

Safir, M., Tobigo, D. T., Mangitung, S. F., Madinawati, M., & Zainab, Z. (2020). Masculinization of Banggai Cardinalfish (*Pterapogon kauderni*) Using 17 α -Methyltestosterone-Enriched *Artemia* Sp. *Omni-Akuatika*, 16(2), 135-140. <https://doi.org/10.20884/1.oa.2020.16.2.809>

Banggai Cardinalfish (*Pterapogon kauderni*) is one of the endemic fish from the waters of the Banggai Islands, Central Sulawesi Province. One factor challenging the production of *P. kauderni* larvae is the male fish will nurture the eggs and larvae for 30 days, hindering next spawning cycle. One effort to overcome this problem an increase of male fish number should be performed, for example through sex reversal. This study aimed to determine the effectiveness of the hormone 17 α -methyltestosterone (17 α -MT) through *Artemia* sp. to increase male sex percentage *P. kauderni*. This study used a completely randomized design by testing four treatments namely feeding *Artemia* sp. which has been soaked with 2.0 mg of the 17 α -MT hormone for two- hours given to *P. kauderni* larvae for 10 days (A); 20 days (B); 30 days (C), and without hormone treatment 17 α -MT (control). Each treatment included control was performed in triplicates. The percentage of male sex was 93.33 % at 30 days treatment and was higher (P 0.05) with those of control. In conclusion, *Artemia* sp. contained 17 α -methyltestosterone enhanced male percentage of *P. kauderni*.

Safir, M., Tobigo, D. T., Mangitung, S. F., Sambaeni, D., Ryaldi, M., Adam, R. D., . . . Husain, H. (2020). Survival Rate and Growth of *Pterapogon kauderni* Larvae Given Different Feed Types. *Jurnal Ilmiah AgriSains*, 21, 1-7. Retrieved from <http://jurnal.untad.ac.id/jurnal/index.php/AGRISAINS/article/view/14593>

This research was conducted to determine the type of feed that provides high survival and growth in *Pterapogon kauderni* larvae after release from the mother's mouth. The study was designed using three treatments including; commercial feeding (A), shrimp/Acetes (B), and rotifer/ Rotifera sp. (C). Each treatment was given three replications. Feed is given three times a day (morning, afternoon and evening) by at-satiation. Maintenance time is carried out for one week. The analysis showed that the highest daily growth rate occurred in treatment B (1.39 \pm 0.92%), and was significantly different (P 0.05). In conclusion, the type of feed that provides the highest survival and growth in *P. kauderni* larvae after release from the mother's mouth is rotifers.

Sugama, K. (2016). Spawning and Growth of Banggai Cardinal Fish (*Pterapogon kauderni*). *Jurnal Riset Akuakultur*, 3, 83-90. <https://doi.org/10.15578/jra.3.1.2008.83-90>

The banggai cardinal fish (*Pterapogon kauderni*), endemic to the Banggai Island of Central Sulawesi in Indonesia, is extensively traded in the International aquarium market. This fish is very close to being placed on the endangered species (CITES) list because of over collection. In Indonesia, no report on breeding study of this fish being reporting. Present report dealing with spawning and growth of fish reared in concrete tanks. This fish is nocturnal feeder eating primarily crustacean, formed in pairs and easy to breed in a concrete tank. The fish spawned in night time (19:30--21:00 pm.), number of eggs spawned by two females are 32 and 38, with diameters of 240--308 micron. Fertilized eggs incubated in

mouth of male for 18--19 days and released the young fish (BL 1.16 cm) to the water within 3--4 days after hatched. The young fish produced from three pairs are ranged from 12 to 32 fish (average 21 fish), and the fish is able to eat rotifer and *Artemia nauplii*. Based on the present observation, this fish is easy to breed in concrete tank and they tend to spawn several times a year with interval time of 42--50 days. The research directed to increase the fecundity, growth and diseases control is urgently required through improvement of the nutritional value of diets.

Ulum, B., Junaidi, M., & Rahman, I. (2020). The Effect of Feeding Frequency on the Growth and Survival of Banggai Cardinal Fish (Bcf). *Jurnal Kelautan: Indonesian Journal of Marine Science and Technology*, 13(1), 15-23. <https://doi.org/10.21107/jk.v13i1.5938>

The purpose of this study was to determine the effect of feeding frequency on the growth and survival of Banggai Cardinal Fish (BCF), and to determine the optimal frequency and timing of feeding. The study used a Completely Randomized Design (CRD) method with 5 treatments and 3 replications namely treatment P1 = one time feeding at 06.00 (morning), treatment P2 = one time feeding at 18.00 (afternoon), treatment P3 = twice feeding at 06.00 and 18.00, treatment P4 = three times feeding at 06.00, 12.00, and 18.00, treatment P5 = four times feeding at 06.00, 12.00, 18.00, and 24.00. The data obtained were analyzed using ANOVA at 95% confidence level and further tests using (Tukey HSD) to determine the best treatment. The parameters observed were absolute length growth, absolute weight growth, daily growth rate, survival rate and water quality. The results showed the frequency of feeding significantly affected the growth and survival of Banggai Cardinal Fish (BCF). The best treatment was obtained from the treatment of feeding 3 times a day resulting in an absolute length growth of 0.62 cm, an absolute weight growth of 0.20 grams, a daily growth rate of 6.97% / day, a survival rate of 73.3%.

Vagelli, A. A. (2017). Mouthbrooders – the Banggai Cardinalfish. In *Marine Ornamental Species Aquaculture*. (pp. 201-221) <https://doi.org/10.1002/9781119169147.ch13>

The endangered Banggai cardinalfish *Pterapogon kauderni* is emblematic of the overexploitation of marine ornamentals for the aquarium trade. Advice in captive breeding is provided here and encouraged in the hope of reducing demand for wild caught specimens. *P. kauderni* reproduces all year long. It is sexually monomorphic and forms transient pairs. Females attain sexual maturity at ~6 months. The most typical courtship displays are “trembling” and “flash” by females. Males incubate the egg-clutch and fast during incubation. Embryos need ~18–20 days before hatching. Afterwards, they remain within the male's mouth for ~5 days. Juveniles begin exogenous feeding at a larger size than other marine ornamental fishes, which prevents requiring additional egg-incubating/larvae rearing tanks, and culturing small food items. However, they are highly susceptible to a deficiency in HUFAs, and prone to suffer “shock syndrome”. Size of ~5.5 cm TL is attained at six months and ~ 6.5 cm TL at one year at ~26 °C. A new Megalocytivirus virus has been described, which is causing high mortality of imported wild caught Banggai cardinalfish specimens.

Zamrud, M., Ndobe, S., & Laapo, A. (2019). Diagnosis Dan Patologi Infeksi Bakterial *Vibrio* Sp. Pada Ikan Kardinal Banggai (*Pterapogon Kauderni*). *Mitra Sains*, 7, 150-160. Retrieved from <http://mrtg.untad.ac.id/index.php/MitraSains/article/view/81>

The aim of this study to observe the effect rearing time of Banggai cardinalfish were infected with *Vibrio* sp. from mortality rate and verify tissue's abnormalities through histopathology test. Rearing time were 5, 10 and 15 days using a completely randomized design with three replications. Data processing is done by analysis of variance one-way ANOVA. Histology bacterial identification and data were analyzed descriptively. Research conducted at the Installation Building Fish Quarantine of Palu, Microbiology Laboratory of Palu and Histology Laboratory Fish Quarantine of Makassar in April to August 2015. Based on identification, found 8 bacteria of *Vibrio* sp were *V. pelagius*, *V. damsela*, *V. carchariae*, *V. anguillarum*, *V. ordalii*, *V. parahaemolyticus*, *V. alginolyticus* and *V. aerogenes*. The results showed rearing time for 15 days (treatment C) triggered the highest fatality rate of 62% was followed by rearing time 10 days (treatment B) of 52% and 5 days (treatment A) of 44%. Histopathological test showed tissue damage in the gills, kidney, skin and eyes. The results shows the longer rearing time the higher of mortality rate were infected with *Vibrio* sp.

Section II: Ecology

Adel, Y., Yonvitner, & Fadjar Rahardjo, M. (2016). Management of the Banggai Cardinalfish (*Pterapogon Kauderni*, Koumans 1933) Using an Ecosystem Approach (Banggai Island Case Study, Banggai Laut District). *Jurnal Ilmu Pertanian Indonesia*, 21(3), 186-194.
<https://doi.org/10.18343/jipi.21.3.186>

The Banggai cardinalfish (*Pterapogon kauderni*) is endemic to the Banggai Archipelago. The conservation status of *Pterapogon kauderni* in the IUCN Red List of Threatened Species is Endangered, *Pterapogon kauderni* is considered to be threatened with extinction due to excessive exploitation as well as threats to its habitat in shallow coastal waters of 0-5 m depth. The aim of this research was to evaluate this fisheries resource using ecosystem-based indicators and to formulate fisheries management measures using an ecosystem-based approach. The six domains used in this evaluation were the fisheries resource domain, habitat and ecosystem, fishing technology, social, economic, and institutional, using a specific set of indicators for each domain. The evaluation produced the following overall, mean, and highest indicator values and domain categories; 3.226.40, 2.33 and 4.204.12 for the fisheries resource domain, poor category; 4.020.80, 2.17, 5.282.36 for the habitat and ecosystem domain, average category; 4.000, 2.00, 6.000 for the fishing technology domain, average category; 6.685, 2.33, 8.505 for the social domain, category; 2.001.74, 1.50 and 3.005.17 for the economic domain, poor category; and 3.041.38, 2.17, 4.564.12 for the institutional domain, average category.

Moore, A., Ndobe, S., Ambo-Rappe, R., Jompa, J., & Yasir, I. (2019). *Dietary Preference of Key Microhabitat Diadema Setosum: A Step Towards Holistic Banggai Cardinalfish Conservation*. Paper presented at the IOP Conference Series: Earth and Environmental Science.
<https://iopscience.iop.org/article/10.1088/1755-1315/235/1/012054>

The sea urchins *Diadema setosum* and *D. savignyi* are key symbionts of the Banggai cardinalfish *Pterapogon kauderni*, a species of global and national conservation concern. There is growing interest in *Diadema* propagation for conservation and human consumption; however little is known about the dietary preferences of Indo Pacific *Diadema* species. This study explored the feeding preference of *Diadema setosum* offered a choice of two macroalgae (*Ulva reticulata*, *Gracilaria* sp.) and two seagrasses (*Thalassia hemprichii*, *Enhalus acoroides*). Portions (5g) of the four feeds were attached to the corners of rectangular plastic cages and one *D. setosum* released in the centre of each cage. Uneaten feed was weighed after 24 hours. This procedure was repeated for 5 days with 8 replicates. Mean daily feed consumption/urchin was 4.31g. All urchins ate a varied diet comprising all four feed types, with a significant preference ($p < 0.01$) for macroalgae (on average 80%). Our results point to an important role of *D. setosum* in macroalgal control; however this urchin might graze on cultivated seaweeds. Further research avenues include the use of macroalgae in prepared feeds for *Diadema* culture, including in the context of *P. kauderni* microhabitat rehabilitation.

Moore, A., Ndobe, S., & Jompa, J. (2017). A Site-Based Conservation Approach to Promote the Recovery of Banggai Cardinalfish (*Pterapogon Kauderni*) Endemic Populations - Konsep Konservasi Berbasis Kawasan Dalam Rangka Pemulihan Populasi Endemik Banggai Cardinalfish (*Pterapogon Kauderni*). *Coastal and Ocean Journal*, 1. Retrieved from
<https://www.coj.pksplipb.or.id/index.php/coj/article/view/44>

The endemic Banggai cardinalfish (*Pterapogon kauderni*) is an Indonesian conservation priority with Endangered species. The goal of this research was to develop a site-based conservation concept appropriate from a bio-ecological viewpoint, based on the unusual characteristics of this species, in particular: (i) mouthbrooder with direct development, leading to reproductively isolated stocks and fine scale genetic structure; (ii) high level of reliance on habitat, in particular symbiosis with benthic animals providing protective micro-habitat. Methods used include review and analysis of published literature and unpublished data, including an analysis using the Marxan spatial planning software. We suggest several policy options and identify research needs, including: (i) base *P. kauderni* conservation (protection, rehabilitation and sustainable use) on stocks as the basic management unit; (ii) use data on *P. kauderni* genetic stocks in the zonation of the proposed Banggai Archipelago marine protected area (MPA); (iii) undertake further research to identify stocks/stock boundaries; (iv) apply the "BCF gardens" concept to fine-scale rebuilding of *P. kauderni* populations and enabling sustainable use through micro-habitat rehabilitation, with a community-based approach supported by a multi-phase scientific research program. The outputs from this study should support efforts towards sustainable management of the Banggai cardinalfish, particularly in the context of strategies to develop and manage an effective sub-national MPA.

Moore, A., Ndobe, S., Salanggon, A.-I. M., & Wahyudi, D. (2018). *Coral Reefs of Sonit Island, Banggai Archipelago: Biodiversity and Management Issues*. Paper presented at the Simposium Nasional Kelautan dan Perikanan. <https://osf.io/preprints/marxiv/c68mu/>

The Banggai Archipelago, situated at the heart of the coral triangle global centre of marine biodiversity, is renowned for endemism. Sonit, one of the most isolated inhabited islands in the archipelago, has been designated under the proposed District MPA. Data and information on the coral reef ecosystem of the island are very limited. Our survey aimed to provide initial biodiversity data, especially for corals. Coral ecosystem biodiversity data were collected using a swim survey method, and corals were identified to Genus level using the Indo-Pacific Coralfinder. General condition of the coral reef ecosystem was estimated using the manta Tow technique. Biophysical data were complemented by socio-economic data using Key Informant Interview (KII). Thirtythree hard coral genera were identified and the results indicate high coral biodiversity. Overall condition was considered Average. Reef-associated organisms included the endemic Banggai cardinalfish (*Pterapogon kauderni*), although on Sonit Island this species tends to be found in the seagrass meadows in the relatively sheltered lagoon. The survey found indications of high fishing pressure on finfish and invertebrates. Damage from mining coral as a building material was clearly visible and likely to get worse under the planned reconstruction and development following infrastructure damage from tectonic activity including a change in elevation. Physical damage to the reef structure is increasing the vulnerability of Sonit Island ecosystems and inhabitants to climate change. We conclude that from a biodiversity viewpoint Sonit Island seems to warrant marine protected area status, however there is a need to address socio-economic aspects and to seek a sustainable development pattern for this small island.

Moore, A. M., Asmi Citra Malina, T., Ambo-Rappe, R., Inayah, Y., Smith, D. J., & Jompa, J. (2019). Unexpected Discovery of *Diadema Clarki* in the Coral Triangle. *Marine Biodiversity*, 49(5), 2381-2399. <https://doi.org/10.1007/s12526-019-00978-4>

Sea urchins of the genus *Diadema*, key herbivores in coral reef ecosystems, also provide habitat for other organisms. Our research extended *Diadema* biogeography in seaways east and west of Sulawesi and

identified *Diadema* species associated with the endemic Banggai cardinalfish (*Pterapogon kauderni*) using field surveys and molecular DNA barcoding methods. Field observations (20 sites, n = 11,223) found urchins with morphological phenotypes typical of *Diadema setosum* ($\approx 74\%$, all sites), *D. savignyi* ($\approx 24\%$, 19 sites) and atypical or mixed traits ($\approx 2\%$, 19 sites). Distribution of these phenotype groups across the three main habitat types (i.e. coral reef, reef flat and seagrass beds) differed significantly ($\chi^2 = 533.03$, $p < 2.2e-16$), indicating overlapping but non-equivalent ecological niches. *Pterapogon kauderni* associated with all urchin morphological phenotypes present. *Diadema* mtDNA CO1 sequences were obtained from tissue samples collected (4 sites, n = 62) from specimens with typical *D. savignyi* and *D. setosum* phenotypes. Phylogenetic tree analysis resolved the sequences into four clades. Three clades from our analysis were identified as *D. savignyi*, *D. setosum* and *D. clarki* based on additional sequences obtained from GenBank. This unexpected first record of *D. clarki* mtDNA in the Coral Triangle implies a substantial extension of the known range of this recently resurrected species. Our findings indicate the occurrence and/or introgression of *D. clarki* may be widespread, and misidentification of *Diadema* urchins based on external morphology may be relatively common. Further research is required to determine the distribution and functional roles of Indo-Pacific *Diadema* species, contributing to our understanding of processes underpinning biodiversity..

Moore, A. M., Ndobe, S., Yasir, I., Ambo-Rappe, R., & Jompa, J. (2019). *Banggai Cardinalfish and Its Microhabitats in a Warming World: A Preliminary Study*. Paper presented at the IOP Conference Series: Earth and Environmental Science.

<https://ui.adsabs.harvard.edu/abs/2019E&ES..253a2021M>

Global changes in the Anthropocene are affecting marine ecosystems in many ways, including alterations in long-established inter-species relationships. The Banggai cardinalfish *Pterapogon kauderni*, a species of global conservation concern, is highly dependent on benthic organisms serving as microhabitat. The objective of this study was to evaluate the effects of global change, in particular rising sea temperature, on *P. kauderni* and three key associated microhabitats: hard corals (Scleractinia), sea urchins (Diadematidae), and sea anemones (Actinia). Data collected before, during, and after the 2016 global coral bleaching event from *P. kauderni* habitat in the Banggai Archipelago, including coral bleaching (by genus) and *P. kauderni* (by life stage) microhabitat association (species or genus, coral life-form), were complemented by a literature review. While coral bleaching and mortality was less severe than in many other regions, hard coral genera and life-forms preferred by *P. kauderni* were disproportionately affected, and *P. kauderni* hosting sea anemones also bleached. Coral, sea urchin and sea anemone reproduction, larval development, and recruitment may be negatively affected. Likely post-settlement effects on sea urchin and sea anemone growth and survival are unclear. Direct impacts on *P. kauderni* are likely, including metabolic rate change with consequences for growth and longevity. Indirect impacts (e.g. changes in plankton composition and abundance, increased storm frequency/severity) will affect *P. kauderni* and all its microhabitats. This evaluation for *P. kauderni*, its key microhabitat groups, and their association, points towards increased need for both conservation action and research to fill identified knowledge gaps.

Moore, A. M., Yasir, I., A-Rappe, R., Ndobe, S., & Jompa, J. (2020). *Asexual Propagation of Two Sea Anemone Taxa for Banggai Cardinalfish Microhabitat Enhancement*. Paper presented at the IOP Conference Series: Earth and Environmental Science.

<https://ui.adsabs.harvard.edu/abs/2020E&ES..473a2011M>

The iconic symbiosis with clownfish is not the only sea anemone-fish association. Several tropical sea anemones provide microhabitat for the Endangered (IUCN Red List) Banggai cardinalfish *Pterapogon kauderni*. Microhabitat loss from declining sea anemone populations is a serious threat to native *P. kauderni* populations or evolutionarily significant units (ESUs). One measure advocated to maintain and rehabilitate these *P. kauderni* ESUs is to restore microhabitat abundance. The objective of this study was to evaluate the feasibility of the asexual propagation of wild anemone broodstock with the subsequent release. Two species with which *P. kauderni* commonly associates (*Heteractis crispa* and *Entacmaea quadricolor*) were identified through field surveys. Parent anemones were bisected, cutting through the center of the oral disc. Propagules (half anemones) were placed in empty clam shells as hard substrate. Treatments provided different levels of protection from potential predators, in aquaria (*P. kauderni* present/absent), concrete tanks (*P. kauderni* and *Diadema* urchins excluded/not excluded) or in a net cage on the natural substrate (fish and invertebrate fauna including *P. kauderni* and *Diadema setosum*). The cut edges of sectioned anemones joined together within seconds, with wounds typically healing in around 7 days and joins hard to see after 3-4 weeks. Growth was faster and long-term survival higher in the net cage compared to tanks for uncovered and covered anemones. The results indicate the potential for this propagation method in the context of *P. kauderni* conservation and suggest sectioned anemones should be moved to the natural rehabilitation areas once capable of adhering firmly to a hard substrate.

Moore, A. M., Yasir, I., Ambo-Rappe, R., Ndobe, S., & Jompa, J. (2020). *Microhabitat Preference of the Banggai Cardinalfish (Pterapogon Kauderni): A Behavioural Experimental Approach*. Paper presented at the IOP Conference Series: Earth and Environmental Sciences. <https://ui.adsabs.harvard.edu/abs/2020E&ES..564a2019M>

The Banggai cardinalfish *Pterapogon kauderni* is an endangered endemic species with an exceptionally small native distribution and an unusual life history. A paternal mouthbrooder with direct development, symbiosis with benthic organisms (referred to as microhabitat), is crucial to its survival. This is especially so for postflexion larvae (recruits), after their release from the male parent's buccal cavity. Microhabitat preference in *P. kauderni* has been studied empirically based on a survey of wild populations. This study adopted an ex-situ experimental approach to *P. kauderni* microhabitat preference using two well established behavioural trial methods: choice flume and choice tank. The experimental animals were sourced from the introduced *P. kauderni* population in Palu Bay, Central Sulawesi, Indonesia. The choice flume method was applied at the Central Sulawesi Marine and Fisheries Service Hatchery in Mamboro, Palu, with microhabitats *Diadema setosum* and *D. savignyi*. The choice box method was applied at the Universitas Hasanuddin Centre for Research and Development in Makassar, South Sulawesi, Indonesia, with microhabitats *Heteractis crispa*, *Entacmaea quadricolor*, *D. savignyi* and *D. setosum*. The results indicate the most to least preferred preference hierarchy of *D. savignyi*, *D. setosum*, *H. crispa*, *E. quadricolor*. While the preference for the sea anemone *H. crispa* compared to *E. quadricolor* is consonant with empirical in situ studies on *P. kauderni*, the observed preference for *D. savignyi* over *D. setosum* was unexpected, and points to the need for further research. Observations made during the trials also raise the possibility that imprinting may occur and influence subsequent microhabitat preference.

Ndobe, S., Jompa, J., & Moore, A. (2018). A Tale of Two Urchins - Implications for in-Situ Breeding of the Endangered Banggai Cardinalfish (*Pterapogon Kauderni*). *Aquacultura Indonesiana*, 19(2), 65-75. <https://doi.org/10.21534/ai.v19i2.110>

The endangered Banggai cardinalfish *Pterapogon kauderni*, endemic to the Banggai Archipelago in Central Sulawesi, Indonesia, is a national and global priority conservation species. To support stock recovery based on in-situ breeding, using the symbiosis between the Banggai cardinalfish and its microhabitat (especially urchins of Genus *Diadema*), specific research objectives were: (i) identify the *Diadema* species associated with Banggai cardinalfish in the wild; (ii) investigate Banggai cardinalfish preference between these *Diadema* species. Belt transect data (5 sites) found wild Banggai cardinalfish of all size classes associated with *Diadema setosum* and *Diadema savignyi*. Preference trials were conducted in a controlled environment (concrete tanks) with three replicates. Nine sub-adult Banggai cardinalfish (35-42 mm SL), 12 *D. setosum* and 12 *D. savignyi* were placed in each tank. Banggai cardinalfish association (*D. savignyi*, *D. setosum*, none) was recorded hourly (06:00-18:00) for three days and results analysed in RStudio-1.0.143. Banggai cardinalfish did not show significant preference for either *D. savignyi* or *D. setosum*. These results indicate that *D. savignyi* and *D. setosum* can be used impartially in further research on in-situ breeding to facilitate recovery of Banggai cardinalfish stocks. However stock recovery measures should consider genetic connectivity and the natural balance between the two urchin species.

Ndobe, S., Moore, A., Salanggon, A. I. M., Muslihudin, n., Setyohadi, D., Herawati, E. Y., & Soemarno. (2016). Banggai Cardinalfish (*Pterapogon Kauderni*) Management an Ecosystem-Based Approach. *Marine Fisheries: Journal of Marine Fisheries Technology and Management*, 4(2), 115-126. <https://doi.org/10.29244/jmf.4.2.115-126>

The Banggai Cardinalfish (*Pterapogon kauderni*) or capungan Banggai (often abbreviated as BCF) is a marine fish endemic to the waters around the Banggai Archipelago, caught in large numbers for the marine aquarium trade. The conservation of this endemic species became an international issue, in 2007 the BCF was proposed for CITES listing by the USA and listed as Endangered in the IUCN Red List. The CITES proposal was withdrawn, with Indonesia committed to conserve the Banggai Cardinalfish through a sustainable ornamental fishery approach. The multi-stakeholder Banggai Cardinalfish Action Plan (2007-2012) and other initiatives have aimed towards this goal; however the initiative to secure limited protected status in 2011 failed. Studies during 2011-2012 found many positive developments in the BCF fishery, and if the carrying capacity (stocks and ecosystems) was similar to the early 2000's, current official exploitation levels should be sustainable. However a stock assessment analysis using FISAT II revealed a high exploitation level (0.5), indicating catches may have reached or possibly exceeded sustainable limits. Survey/monitoring results indicate the endemic population is not in a steady state, with sharp declines in the past decade. There are strong indications that habitat degradation is the main cause of this decline, including over-exploitation of key BCF micro-habitat (sea urchins and sea anemones). Without an effective solution to protect the supporting ecosystem, *P. kauderni* will be increasingly threatened with extinction, with or without fishing pressure. The case of the BCF highlights the importance of an ecosystem-based approach to fisheries policy and management.

Ndobe, S., Moore, A., Ya'la, Z. R., & Madinawati. (2018). *The Sustainable Management Plan Concept of Banggai Cardinalfish (Pterapogon Kauderni)*. Paper presented at the Simposium Nasional Pengelolaan Perikanan Ikan Karang Berkelanjutan Indonesia. <https://osf.io/preprints/marxiv/wqz7t/>

The endemic fish *Pterapogon kauderni*, common name Banggai cardinalfish (BCF), is listed as Endangered in the IUCN (International Union for the Conservation of Nature) Red List. *Pterapogon*

kauderni management using a sustainable ornamental fishery approach is a component of the Indonesian National Plan of Actions (NPOA) under the Coral Triangle Initiative for Coral reefs, Fisheries and Food Security (CTI-CFF). A Banggai Cardinalfish Fisheries Management Plan (RPP-BCF) was a target of the 2007-2012 multi-stakeholder program designed in 2007 after the Conference of the Parties to CITES (Convention on the International Trade in Endangered Species of Wild Fauna and Flora). This target has yet to be achieved, and the RPP-BCF is included in the Ministry of Fisheries and Marine Affairs 2015-2019 program. The management plan concept proposed here is based on EAFM (Ecosystems Approach to Fisheries Management) principles, up-to-date scientific knowledge, developments in *P. kauderni* biological and ecological status and exploitation since 2004, as well as discussions on a draft RPP-BCF at the Regional Fisheries Management Meeting (FKKPS) in March 2015. This concept is intended to inform form a scientific perspective compilation and implementation of an RPP-BCF, in line with legal norms and existing legislation, which could lead to sustainable management of *Pterapogon kauderni*, particularly within the natural distribution of this endemic species.

Putra, I. N. G., & Putra, I. D. N. N. (2019). Recent Invasion of the Endemic Banggai Cardinalfish, *Pterapogon Kauderni* at the Strait of Bali: Assessment of the Habitat Type and Population Structure. *ILMU KELAUTAN: Indonesian Journal of Marine Sciences*, 24(1), 15-22.
<https://doi.org/10.14710/ik.ijms.24.1.15-22>

The demands of marine organisms for the aquarium trade are remain high and seems continue to increase. Consequently, many of marine organisms has been spread out from its natural habitat as in the case of endemic Banggai cardinalfish, (*Pterapogon kauderni*). That has invaded “new” habitat since it being trade in 1995. In recent years, a small populations of *P. kauderni* is known to be exist in a narrow bay near the Gilimanuk harbor, Bali. An underwater visual fish census survey was conducted on June 2018 to estimate the habitat types and densities of *P. kauderni*. Additionally, 23 specimens of *P. kauderni* were collected randomly in order to assess biological parameters such as the length-weight relationship. We successfully recorded 30 groups of *P. kauderni* that inhabit a shallow areas with a depth range between 0.5m to 2m. Of these, more than 90% of the groups were found to be associated with sea urchin (*Diadema* sp.) while the rest were found to live together with branching coral (*Acropora* sp.) and branching sponge (*Ptylocaulis* sp.). Total number of fish observed during the survey were 381 individuals. The fish density is 0.76 individu.m⁻². Length-weight relationship showed that *P. kauderni* exhibit is negative allometry ($b < 3$) which mean that the increase in length is faster than the weight gain. Interestingly, from the 23 specimens collected, none of these were sexually mature ($SL < 41$ mm) which may indicated that the population of *P. kauderni* in Bali are under serious threats of exploitation.

Section III: Population

Carlos, N. S. T., Rondonuwu, A. B., & Watung, V. N. R. (2015). Distribusi Dan Kelimpahan Pterapogon Kauderni Koumans, 1933 (Apogonidae) Di Selat Lembeh Bagian Timur, Kota Bitung. *JURNAL ILMIAH PLATAX*, 2(3), 121-126. <https://doi.org/10.35800/jip.2.3.2014.9124>

This study was aimed at knowing the distribution of Banggai cardinalfish, *Pterapogon kauderni*, using haphazard survey method. Data collection was done in Lembeh Strait, Mawali, Batu Lubang, and Kareko. The fish found in 3 locations inhabited several habitats, such as anemone, corals, can, garbage, and sea urchin, in which sea urchin *Diadema* sp., is the habitat outnumbering the other habitats and the most used. The interesting point of this study is the fish were recorded in branching corals, and even there was one site where sufficient number of branching coral colonies was used as the habitat of *Pterapogon kauderni*. Thus, this study suggested that the distribution of *Pterapogon kauderni* will follow the natural habitat condition and not be always dependent upon the sea urchin colony.

Hartati, S. T., & Kasim, K. (2017). Cohort Distribution and Spawning Potential Ratio of Banggai Cardinal Fish (*Pterapogon Kauderni*, Koumans 1933) Using Lb-Spr Model in Banggai Archipelago Central Sulawesi *Jurnal Penelitian Perikanan Indonesia*, 22(3), 197-206. <https://doi.org/10.15578/jppi.22.3.2016.197-206>

Banggai cardinal (*Pterapogon kaudernii*) fish is an endemic species which is traded as an ornamental fish. Population parameters such as length distribution and ages of *P. kaudernii* are required to estimate status of the species as a part of management purposes. This study aimed to determine the stock status of Banggai cardinal through estimation of the age groups and use that information as biological reference point to estimate the Spawning Potential Ratio (SPR) through Length-Based SPR model. Length of fish samples were measured of 7,014 fish samples during the year 2010 to the year 2011 while gonadal maturity, fecundity and sex differentiation were obtained from 394 individuals fish samples. The results show that fisherman caught mostly young individual fish, aged 10-11 months with relative length 32.7 - 35.2 mm FL and at below the size of length at first maturity (L_m) of 36.1 - 44.4 mm FL. Estimation of SPR shows that stock has been in healthy status which indicated by average SPR of 44.6% which still above the overfishing threshold by 30%. However, the values of SPR were declined significantly from 46.8% in 2010 to be 40.4% in 2011. As many as 50% of mature female fish found on the size of 37 mm FL and 50% caught (Selectivity/ SL_{50}) on the size of 32 mm FL ($SL_{50} < L_{50}$). The rate of relative fishing mortality (F) to natural mortality (F / M) of 0.57 indicates relative fishing effort has reached 57% of the rate of natural mortality.

Huwae, R., Patty, S. I., Arbi, U. Y., & Hehuwat, J. (2019). Preliminary Study on Banggai Cardinal Fish Square Population (*Pterapogon Kauderni*, Koumans 1933) in Inner Ambon Bay. *Jurnal Ilmu Kelautan Kepulauan*, 2. <https://doi.org/10.33387/jikk.v2i1.1192>

Pterapogon kauderni is one of Indonesia's endemic marine ornamental fish species which has high commercial value in the international ornamental fish trade. The population of this fish in the natural habitat has markedly decreased due to overfishing with no regard to biological or ecological aspects. Observation of Banggai Cardinal fish in Inner Ambon Bay was carried out to determine the population size and estimated fish stocks. The results showed that the highest fish population was found in the Poka location with a density value of 0.17-0.42 tails/ m^2 and the estimated population reached 25411

tails. The lowest fish population is in Waiheru with a density of 0.05-0.06 tails/m² and the estimated population reaches 2556 tails. The abundance of ornamental fish populations is closely related to abundance of sea urchins which is a micro habitat mainly in seagrass and coral reefs.

Moore, A. M., Ndobe, S., & Inayah, Y. (2021). Importance of Monitoring an Endangered Endemic Species - Intra-Species Biodiversity Perspectives on the Banggai Cardinalfish Conservation and Trade. *IOP Conference Series. Earth and Environmental Science*, 681(1). <https://doi.org/10.1088/1755-1315/681/1/012120>

The Banggai cardinalfish *Pterapogon kauderni* is a marine ornamental fish with an exceptionally limited natural (endemic) distribution with IUCN Red List status Endangered. An object of national and global concern, conservation efforts have been hindered by misconceptions regarding key concepts (e.g. endemism) and a lack of routine and standardised monitoring of *P. kauderni* populations, fishery and trade. This study approached *P. kauderni* conservation, including sustainable exploitation, from an intra-species biodiversity perspective, based on IUCN definitions and the evolutionarily significant unit (ESU) concept, with a focus on the importance of monitoring. Analysis of monitoring data combined with knowledge of the unusual life-history and unusually fine-scale genetic structure of *P. kauderni* were used to identify monitoring priorities and methodological recommendations to support holistic *P. kauderni* management at the ESU level, within the endemic range. Some implications of introduced wild populations and captive breeding were also evaluated. The analysis highlights the need for an interdisciplinary approach and inter-sectoral collaboration in monitoring for management. In particular, to combine information from field surveys with trade data (e.g. Fish Quarantine records), and to keep long-term records, to avoid shifting baselines due to the current typically limited periods of data availability.

Ndobe, S., Handoko, K., Wahyudi, D., Yasir, M., Irawati, Y., Tanod, W. A., & Moore, A. (2020). Monitoring the Endemic Ornamental Fish *Pterapogon kauderni* in Bokan Kepulauan, Banggai Marine Protected Area, Indonesia. *Depik*, 9(1), 18-31. <https://doi.org/10.13170/depik.9.1.15363>

The Banggai cardinalfish *Pterapogon kauderni* is a species of national and international conservation concern. Established in November 2019, the Banggai marine protected area (MPA) in Central Sulawesi, Indonesia covers most of the endemic range of this ornamental fish. The third repeat survey (T2 monitoring) under the National Action Plan for Banggai Cardinalfish Conservation (NAP-BCFC) was carried out in October 2019 at eight sites in the Bokan Kepulauan region within the MPA. The T2 monitoring used the standard NAP-BCFC belt transect method. Data were collected on *P. kauderni* abundance (by size class: recruits, juveniles, adults) and microhabitat (sea urchins, sea anemones, hard corals, and others). Data were evaluated with respect to the T0 (2017) survey and T1 (2018) monitoring at the same sites, as well as previous surveys in 2004 (2 sites) and 2012 (4 sites). The data show wide between-site variation in *P. kauderni* and microhabitat parameters, with one subpopulation at very high risk of extirpation. Trends included declines over time in *P. kauderni*, sea urchin and sea anemone abundance, with an increase since 2017 in hard coral microhabitat use by adult *P. kauderni*. We recommend evaluation of other *P. kauderni* populations in Bokan Kepulauan and specific site or zone-based actions. However, we conclude that the most urgent priority for *P. kauderni* conservation in Bokan Kepulauan is protection of key microhabitat through a moratorium on sea urchin and sea anemone collection in *P. kauderni* habitat.

Wiadnyana, N. N., Suharti, S. R., Ndobe, S., Triharyuni, S., Lilley, G. R., Risuana, S., . . . Moore, A. M. (2020). *Population Trends of Banggai Cardinalfish in the Banggai Islands, Central Sulawesi, Indonesia*. Paper presented at the IOP Conference Series: Earth and Environmental Science. <https://ui.adsabs.harvard.edu/abs/2020E&ES..420a2033W>

The Banggai cardinalfish (BCF) (*Pterapogon kauderni*) is endemic to the Banggai Archipelago, Indonesia and has received international attention due to the decline in its population. As the sole range state, Indonesia has a responsibility to conserve the BCF through initiatives for its sustainable management. To inform management and evaluate management effectiveness, a research program has been set up to monitor BCF populations at 24 sites. The initial (T0) baseline survey in 2017 was followed by the first annual monitoring (T1) in 2018. At each site, data collected in 6 belt transects (20 x 5m) comprised BCF density by size class, and microhabitat density (sea urchins and sea anemones). The Students t-test was applied to test for significant differences in BCF population density between T0 and T1 results, and correlation with influencing factors was evaluated using multiple regression ($\alpha = 0.05$). The overall adult population trend was positive, despite declines in BCF density at some sites. BCF density was positively correlated with both sea urchin and sea anemone densities; however, the correlation with sea anemone density was stronger. These results reinforce the importance of protecting sea anemone and sea urchin microhabitat, as part of a holistic approach to rehabilitating and sustaining BCF stocks.

Wibowo, K., Arbi, U. Y., & Vimono, I. B. (2019). *The Introduced Banggai Cardinal Fish (*Pterapogon kauderni*) Population in Ambon Island, Indonesia*. Paper presented at the IOP Conference Series: Earth and Environmental Science. <https://ui.adsabs.harvard.edu/abs/2019E&ES..370a2041W>

The Banggai cardinalfish *Pterapogon kauderni* (commonly referred to as BCF) is a fish endemic to the Banggai Islands, Central Sulawesi. Recently, Banggai cardinalfish have been introduced to several regions in Indonesia as a side effect of Banggai cardinalfish trading and mariculture. BCF juveniles cultured by the Balai Perikanan Budidaya Laut (BPBL) Ambon were released in several locations around Ambon Bay during 2014 - 2017. Around 20 - 500 BCF were released at each location. This study was carried out in April 2018 as a first monitoring of Banggai cardinalfish population status at all "restocking" locations in Ambon Bay. The data were collected by SCUBA diving using a Belt Transect method, with BCF size classes based on standard length (SL). The results found Banggai cardinalfish at three out of five monitoring locations. The first location was the Ferry Port, where 20 Banggai cardinalfish were released in 2014; the BCF density was 41 fish/100 m², dominated by adults (> 3.5 cm SL). The second location was behind the Natural Sciences Faculty of Pattimura University where 20 Banggai cardinalfish were also released in 2014; the density was 73 individuals/100 m² (with evenly distributed size). The third location was the bridge behind the SUPM campus, where 500 Banggai cardinalfish were released in 2016, but only 2 fish/100 m² (adults > 3.5 cm SL) were found during the study. No Banggai cardinalfish were found at the other two locations, namely the Port of Ambon and Suli Beach, although there were 500 individuals were released at each of those two locations in 2016 and 2017. These result shows that BCF have been able to adapt and breed rapidly in some coastal areas in Ambon Bay that provide suitable habitat for Banggai cardinalfish.

Section IV: Threats

Adriany, D. T., & Koesharyani, I. (2018). Diseases Infection in Banggai Cardinal (*Pterapogon Kauderni*) in Trade Chain. *Jurnal Riset Akuakultur*, 12(3), 283-294.
<https://doi.org/10.15578/jra.12.3.2017.283-294>

Banggai cardinal fish is an ornamental fish endemic to the Banggai Islands, Central Sulawesi. It has been exploited since 1980's. Banggai Cardinal fish has been export to various countries. However, with many cases of infectious diseases such as bacteria and virus Banggai Cardinal Iridovirus (BCIV), the demand for Banggai Cardinal from Indonesia is declining. The purpose of this study is to trace and inventorize the flow of disease infections in the trade chain of ornamental fish from fisherman, to collectors, and exporters. The analysis was done by taking samples of 15 fish from each trade chain. Observations included examination of parasites, fungi, bacteria, and BCIV analysis. The results showed that no parasite and fungus infecting the fish in all trades chains. Seven bacteria species have been indentified from the fish samples from all trades chains and *Vibrio alginolyticus* was the common pathogenic bacteria species infecting the fish. Infection of BCIV was found in one of collectors' warehouse in Luwuk with the prevalence of 86.67% and at the exporters in Bali and Manado with the prevalence rate of 20% and 50% respectively. Based on the present results, we suggest that exporters must exercise a rigorous prevention program of the disease in order to be able to compete in the ornamental fish world market.

Akmal, S. G., Brigitta, P. D. Z.-W., Prabowo, R. E., Khatami, A. M., Novák, J., Petrtyl, M., . . . Patoka, J. (2020). Marine Ornamental Trade in Indonesia. *Aquatic Living Resources*, 33.
<https://doi.org/10.1051/alr/2020026>

Trade with marine species as ornamentals is an important sector of the international pet trade. The vast majority of these species are collected from the wild and one of the top supplying countries is Indonesia. Detailed evidence on trade with marine resources in Indonesia is lacking or it is hardly accessible. Moreover, the exploitation of ornamental species seems to be mostly uncontrolled. This study presents detailed characteristics of such trade for Indonesia, including the offered species, their sizes, prices, and conservation status, based on data and information obtained from wholesalers in 2018. The main provinces of marine wildlife collecting are also identified. In total, 777 marine vertebrate and invertebrate species were traded, belonging to 174 families including two species classified as endangered: Banggai cardinal fish (*Pterapogon kauderni*) and zebra shark (*Stegostoma fasciatum*). Commonly traded was red lionfish (*Pterois volitans*), known to be a successful invader. The volume of ornamental marine fish exported from Indonesia in period 2015–2019 was 3 353 983 kgs sold for 33 123 218 USD. The province of Bali was identified as the main exporter of ornamental marine fish within Indonesia. These findings should help to establish sustainable exploitation of marine resources in relation to conservation and wildlife management.

Baillargeon, G. A., Tlusty, M. F., Dougherty, E. T., & Rhyne, A. L. (2020). Improving the Productivity-Susceptibility Analysis to Assess Data-Limited Fisheries. *Marine Ecology Progress Series*, 644, 143-156. <https://doi.org/10.3354/meps13362>

Each year, millions of marine aquarium fish and invertebrates are harvested from coral reefs and enter the complex and largely unregulated marine aquarium trade (MAT). It is challenging to identify species at risk of overexploitation in this trade due to its data-limited and poorly monitored nature. We

developed a new analytical approach based on a productivity-susceptibility analysis (PSA) to assess the vulnerability of wild-captured marine aquarium fish. The PSA was originally developed to assess food fisheries; however, species and operational characteristics between food fisheries and the MAT differ. Thus, we improved a prior PSA framework to assess the data-limited MAT through customization of productivity and susceptibility factors to align with the target fishery, improved data binning, calculation of susceptibility, and characterization of the vulnerability scores. Our vulnerability results align well with the most recent IUCN assessments, showing improved accuracy using this revised PSA compared to prior adaptations of the PSA to the MAT. Further, we show that this PSA approach can be used to assess species on either a global or country-specific scale. A Gaussian mixture model clustering algorithm was applied to the PSA results to objectively classify fish along a sustainability continuum. Among 32 species, a majority of species clustered as highly sustainable or sustainable indicating little management or over-harvest concern; however, the Banggai cardinalfish *Pterapogon kauderni* and blue tang *Paracanthurus hepatus* indexed as unsustainable. This novel PSA method, and use of a clustering algorithm to classify results, provides a predictive tool for a wide range of fisheries. In addition to informing species management plans, the compilation of sustainability status data generated by our PSA can inform a consumer guide, allowing consumers and other stakeholders to make sustainable decisions when purchasing fish.

Biondo, M. V. (2017). Quantifying the Trade in Marine Ornamental Fishes into Switzerland and an Estimation of Imports from the European Union. *Global Ecology and Conservation*, 11, 95-105. <https://doi.org/https://doi.org/10.1016/j.gecco.2017.05.006>

Millions of marine ornamental fishes are traded every year. Today, over half of the known nearly 4000 coral reef fish species are in trade with poor or no monitoring and demand is increasing. This study investigates their trade into and through Switzerland by analyzing import documents for live animals. In 2009, 151 import declarations with attached species lists for marine ornamental fishes from non-EU countries totaled 28 356 specimens. The 62% of the fishes remaining in Switzerland, comprised 440 marine species from 45 families, the rest transited to EU and non-EU countries. Despite the recognized large trade volume for the European region, due to bilateral agreements, no data is collected for imports from the EU. However, inferred data shows that more than 200 000 marine ornamental fishes could be imported into Switzerland every year and an unknown quantity re-exported. As biggest import region, it is therefore safe to assume, that the European region is importing at least as many marine ornamental fishes as the US. There is no adequate data-collecting system known to be in place in any country for monitoring this trade. The EU Trade Control and Expert System (TRACES) to monitor animal diseases could be adjusted to gather compulsory information for the EU and Switzerland. More than half of the species imported into Switzerland are not assessed by the IUCN and therefore marked as 'not evaluated' on the Red List. Overall, 70% of all known coral reef fish species have not been evaluated. If coral reef fishes are threatened or endangered due to large, possibly unsustainable numbers traded, it may be rational to monitor the trade in these species through the Convention on International Trade of Endangered Species (CITES).

Che Azarulzaman Che, J., & Zainathan, S. C. (2020). Megalocytiviruses in Ornamental Fish: A Review. *Veterinary World*, 13(11), 2565-2577. <https://doi.org/http://www.doi.org/10.14202/vetworld.2020.2565-2577>

Iridoviruses, especially megalocytiviruses, are related to severe disease resulting in high economic losses in the aquaculture industry worldwide. The ornamental fish industry has been affected severely due to Megalocytivirus infections. Megalocytivirus is a DNA virus that has three genera; including red sea bream iridovirus, infectious spleen and kidney necrosis virus, and turbot reddish body iridovirus. Megalocytivirus causes non-specific clinical signs in ornamental fish. Cell culture, histology, immunofluorescence test, polymerase chain reaction (PCR) assay, and loop-mediated isothermal amplification assay have been used to diagnose megalocytiviruses. Risk factors such as temperature, transportation (export and import), and life stages of ornamental fish have been reported for the previous cases due to Megalocytivirus infections. In addition, other prevention and control methods also have been practiced in farms to prevent Megalocytivirus outbreaks. This is the first review of megalocytiviruses in ornamental fish since its first detection in 1989. This review discusses the occurrences of Megalocytivirus in ornamental fish, including the history, clinical signs, detection method, risk factors, and prevention measures.

Dee, L. E., Karr, K. A., Landesberg, C. J., & Thornhill, D. J. (2019). Assessing Vulnerability of Fish in the U.S. Marine Aquarium Trade. *Frontiers in Marine Science*, 5, 527.
<https://doi.org/10.3389/fmars.2018.00527>

The trade in coral reef fishes for aquariums encompasses over 1,800 species from over 40 exporting countries, yet the population status for most traded species is unknown and unevaluated. At the same time, these coral reef fishes face a growing number of threats and often occur in jurisdictions with limited management capacity and data. In response, we assess vulnerability to overfishing for 72 coral reef fishes popular in the aquarium trade for the United States – the top importer – from the top exporting countries (Indonesia and the Philippines). We use a data-limited assessment approach: productivity susceptibility analysis (PSA). PSA estimates relative vulnerability of species by assessing their biological productivity and susceptibility to overfishing. The most and least vulnerable stocks were differentiated by attributes related to the reproductive biology (e.g., breeding strategy, recruitment pattern, and fecundity), appropriateness, ease of capture (e.g., schooling and aggregation), and rates of natural mortality. Our analysis identifies several of the most and least vulnerable species popular in the aquarium fish trade. The species that ranked as least vulnerable to overcollection were *Gobiodon okinawae*, *Nemateleotris magnifica*, *Gobiodon acicularis*, *Salarias fasciatus*, *Ptereleotris zebra*, *Gobiodon citrinus*, *Pseudocheilinus hexataenia*, *Chaetodon lunula*, *Nemateleotris decora*, and *Halichoeres chrysus*. In contrast, the ten most vulnerable species were *Chromileptes altivelis*, *Plectorhinchus chaetodonoides*, *Pterapogon kauderni*, *Premnas biaculeatus*, *Echidna nebulosa*, *Centropyge bicolor*, *Zebrasoma veliferum*, *Pomacanthus semicirculatus*, *Zebrasoma scopas*, and *Thalassoma lunare*. In a data-limited context, we suggest how these vulnerability rankings can help guide future efforts for reducing vulnerability risk. In particular, species that are relatively high-vulnerability and high-volume are prime targets for research and aquaculture efforts, increased monitoring of collection and exports, species-specific stock assessments, and voluntary reductions by retailers and consumers to avoid overexploitation.

Mardiastuti, A., & Soehartono, T. R. (2020). Banggai Cardinalfish (*Pterapogon Kauderni*) and the Attempt for the Inclusion of Cites Appendix Ii. *Jurnal Ilmu dan Teknologi Kelautan Tropis*, 12(2), 597-607.
<https://doi.org/10.29244/jitkt.v12i2.30944>

Banggai cardinalfish (*Pterapogon kauderni*) is a commercial ornamental fish originated and endemic to Banggai Islands of Indonesia. The objective of this paper was (a) to examine the sequence and the reasons to include Banggai cardinalfish into CITES Appendix II by USA and again by European Union, (b) to explain the responds (policy and actions) by Indonesian Government, and (c) to analyse the impact of the international and national policies related to CITES decisions. Basically, USA and EU claimed that the exploitation of Banggai cardinalfish for export was over-harvested and unsustainable, and thus they proposed to include the species into CITES Appendix II. The Government of Indonesia considered that the species has been appropriately managed in accordance to sustainable yield, and thus this species no need to include in the CITES Appendix II. To ensure its sustainability, the Government has issued a number of activities and interventions, among other, imposing limited access to harvest area, establishment of breeding operations, study of its natural population as well as development of a national action plan. After a long process involving various institutions, Banggai cardinalfish was decided not to be included in CITES Appendix II. Conservation measures, however, need to be continued by Indonesian Government to make sure that the population and the trade of Banggai cardinalfish will be sustainable in the future.

Moore, A., Ndobe, S., & Jompa, J. (2018, 2018/08/10). *Fingerprints of the Anthropocene: The 2016 Coral Bleaching Event in an Equatorial Archipelago*. Paper presented at the The 4th International Marine and Fisheries Symposium 2017. <https://doi.org/10.31230/osf.io/q5frc>

Coral reef ecosystems worldwide are experiencing increasingly frequent episodes of temperature-related "coral bleaching". The Banggai Archipelago in Central Sulawesi, Indonesia, has extensive coral reefs and is home to the endemic Banggai cardinalfish, *Pterapogon kauderni*, a species listed as Endangered in the IUCN red List. A rapid survey was undertaken at seven sites (1.2°S-2°S) in this archipelago, in response to the national call for action during the 2016 global bleaching event. The CoralWatch method (6 point colour scale: CW1-CW6) was used; colony life-form (Global Coral Reef Monitoring Network categories) and genus (Indo-Pacific Coral-finder) were recorded. Partial and full bleaching were observed at all sites; of 1166 colonies, 64.7% were fully bleached (CW1) or very pale (CW2); with 13.5% in CW4-CW6. Water temperatures were 1-3°C above recorded maxima from 2004-2012. Branching and encrusting life-forms had the highest full/severe bleaching rates. Common genera with above average bleaching rates included *Stylophora*, *Seriatopora*, *Pocillopora*, *Isopora*, *Merulina*, *Galaxea*, some forms of *Acropora* and *Porites*. Algal overgrowth was observed on both live (fully/partially) bleached and dead colonies. Densities of *Diadema* sp. urchins, a key symbiont of the Banggai cardinalfish, until recently the most abundant coral reef herbivore, were extremely low (orders of magnitude less than 2004 densities), with few adult individuals present at 5/7 sites. The Caribbean experience underlines the urgency of addressing the unregulated *Diadema* fishery which has developed in the Banggai Archipelago since around 2007. Rehabilitating populations of this key invertebrate herbivore would contribute to biodiversity conservation and reef resilience/recovery in this equatorial archipelago.

Moore, A. M., Ndobe, S., Yasir, I., & Jompa, J. (2019, 2019/04/1). *Disasters and Biodiversity: Case Study on the Endangered Endemic Marine Ornamental Banggai Cardinalfish*. Paper presented at the IOP Conference Series: Earth and Environmental Science. <https://doi.org/10.1088/1755-1315/253/1/012036>

Disasters are notoriously unpredictable; they can strike anytime, anywhere. However, in this Anthropocene Epoch, humanity has increased the likelihood of many disasters, as well as their likely severity and socio-ecological impacts, with implications for the future of natural resources; in particular, marine ecosystems and biodiversity, and the human communities who rely on them. This case study focussed on the Banggai cardinalfish (*Pterapogon kauderni*), a unique species of global conservation concern, and its native habitat in the Banggai Archipelago, at the centre of the Coral Triangle (CT) global marine biodiversity hotspot. To evaluate future risks and implications, we looked back to the past, including an overview of what is known regarding the origins and evolution of this species and its habitat, as well as past natural disasters in the Banggai Archipelago, Central Sulawesi, Indonesia. We then reviewed current status and trends affecting the likelihood of exposure and the vulnerability of endemic *P. kauderni* populations and habitat, overall and at the evolutionary significant unit (ESU) scale, to disasters caused by tectonic phenomena, disasters related to weather and anthropogenic climate change (e.g. mass coral bleaching, sea level rise), and the synergies between disaster impacts and localised human activities. Finally, we considered management options with potential for mitigating disaster risk and increasing resilience, with benefits for both biodiversity and human welfare, as well as avenues for future research. We conclude that local action can buy time, but it is likely that the eventual fate of this “flagship” species, as well as the human communities of this equatorial archipelago, depend on effective global action to curb the drivers of anthropogenic climate change.

Ndobe, S., & Moore, A. (2018). *Peran Sains Dalam Proses Menuju Sustainable Ornamental Fishery: Kasus Banggai Cardinalfish*. Paper presented at the Konferensi Sains Kelautan dan Perikanan Indonesia I. <https://osf.io/preprints/marxiv/cs94p/>

This paper was presented at the Konferensi Sains Kelautan dan Perikanan Indonesia I, Bogor, Indonesia, 17-18 July 2007 and published in the proceedings (pp. MSP: 157-169). The paper discusses the role of science in the process of moving towards a sustainable fishery for the Endangered (IUCN Red List) Banggai cardinalfish (*Pterapogon kauderni*), in the aftermath of CITES CoP 14 in 2007 where the proposal to list the species under CITES Appendix II was withdrawn. Both past contributions and suggestions for the future role of science are addressed.

Ndobe, S., Moore, A., & Jompa, J. (2017). Status of and Threats to Microhabitats of the Endangered Endemic Banggai Cardinalfish (*Pterapogon Kauderni*). *Coastal and Ocean Journal*, 1. Retrieved from <https://coj.pksplipb.or.id/index.php/coj/article/view/45>

The endemic Banggai cardinalfish (*Pterapogon kauderni*) is one of conservation priority marine species in Indonesia. With a conservation status of Endangered, Indonesia has made a commitment to *P. kauderni* conservation, and policy development is underway. *P. kauderni* lives in symbiosis with sea urchins (*Diadema* sp.), sea anemones and branching corals. This research evaluated the current status of and threats to *P. kauderni* microhabitat, including the climate change context. Primary data were collected using Coral-Watch and swim survey methods during the 2016 global bleaching event, and compared with survey data collected since 2004. The study revealed a sharp decline in *Diadema* sp. population abundance as well as reduced sea anemone abundance, in both cases largely due to sharp increases in exploitation by local communities, mostly for human consumption. Corals and other microhabitats had also suffered from increased coral reef degradation related to local-scale destructive human activities, as well as climate-related coral bleaching. Wherever microhabitat availability was greatly reduced, *P. kauderni* abundance had declined sharply, irrespective of fishing pressure on this

species. Microhabitat protection and recovery is considered a sine qua non prerequisite for successful in-situ *P. kauderni* conservation. The results contribute to the scientific basis for sustainable management of endemic *P. kauderni* stocks and habitat.

Ndobe, S., Moore, A., Yasir, I., & Jompa, J. (2019). *Banggai Cardinalfish Conservation: Priorities, Opportunities, and Risks*. Paper presented at the IOP Conference Series: Earth and Environmental Science. <https://ui.adsabs.harvard.edu/abs/2019E&ES..253a2033N>

Human actions are undoubtedly the major factor affecting the biosphere in this Anthropocene era, making it vital to involve all levels of society in the stewardship of natural resources, in particular marine ecosystems and biodiversity. The Banggai cardinalfish *Pterapogon kauderni* is a unique species at risk of extinction and an object of global conservation concern. The endemic range of *P. kauderni* is limited to around 500km², mostly in the Banggai Archipelago, Central Sulawesi, Indonesia. The objective of this study was to evaluate the priorities for *P. kauderni* conservation, with a focus on the recently declared Banggai Dalaka MPA, the National Plan of Action (NPOA-BCF) and the decisions taken at CITES CoP 17 in 2016. Risks identified include the loss of genetic diversity and structure, serial depletion of populations/stocks, loss of identity (“branding” issues), local threats to habitat/microhabitat, and the impacts of global change. Opportunities include local, national and international awareness, the CITES Animal Commission processes, iconic status, and stakeholder capacity. Key priorities identified included: (i) prioritise endemic (not introduced) *P. kauderni* populations; (ii) protect genetic diversity through site/stock-based management (conservation, ornamental fishery, monitoring), initiated using existing genetic population structure data, while seeking to develop a database of genetically unique (reproductively isolated) stocks; (iii) protect and rehabilitate *P. kauderni* habitat and microhabitat (especially *Diadema* urchins and sea anemones) within the Banggai Dalaka MPA; (iv) investigate, record (and where necessary restrict) in-country movements of *P. kauderni*, especially removal from the endemic range (e.g. currently unrecorded shipping to Kendari), as well as export and international movements; (v) regulate and restrict the release of *P. kauderni* to the wild from captivity and/or between known/suspected genetic stocks; (vi) institutionalisation at multiple levels in a holistic socio-ecological context to provide robust and resilient conservation management and capitalise on the “flagship species” potential of the Banggai cardinalfish.

Rhyne, A. L., Tlusty, M. F., & Szczebak, J. T. (2017). Early Culture Trials and an Overview on U.S. Marine Ornamental Species Trade. In *Marine Ornamental Species Aquaculture*. (pp. 51-70) <https://doi.org/https://doi.org/10.1002/9781119169147.ch4>

Summary Ornamental aquarium fishes have been traded globally for centuries. In the last few decades, the trade in marine species has expanded to over 40 countries supplying tropical and temperate marine life for both public and private aquariums. Accurate trade data covering the diversity and magnitude of species are elusive. The poor record keeping by both exporting and importing nations hinders efforts to understand the trade and its implications on marine ecosystems. We provide an overview of a multi-year data set that catalogs the imports of marine aquarium fishes and invertebrates into the United States. Further, we examine the history of marine ornamental aquaculture and assess constraints and bottlenecks to commercial production. We demonstrate that pelagic larval duration (PLD), economics, and regulatory actions are constraints to commercial production, while selective breeding and alternative species are production opportunities. Aquaculture can provide environmental benefits by

reducing collecting pressure on highly traded species, but may carry economic and environmental risks, such as livelihood displacement and increasing the number of tankbusters in trade.

Rhyne, A. L., Tlusty, M. F., Szczebak, J. T., & Holmberg, R. J. (2017). Expanding Our Understanding of the Trade in Marine Aquarium Animals. *PeerJ*, 5, e2949. <https://doi.org/10.7717/peerj.2949>

The trade of live marine animals for home and public aquaria has grown into a major global industry. Millions of marine fishes and invertebrates are removed from coral reefs and associated habitats each year. The majority are imported into the United States, with the remainder sent to Europe, Japan, and a handful of other countries. Despite the recent growth and diversification of the aquarium trade, to date, data collection is not mandatory, and hence comprehensive information on species volume and diversity is lacking. This lack of information makes it impossible to study trade pathways. Without species-specific volume and diversity data, it is unclear how importing and exporting governments can oversee this industry effectively or how sustainability should be encouraged. To expand our knowledge and understanding of the trade, and to effectively communicate this new understanding, we introduce the publically-available Marine Aquarium Biodiversity and Trade Flow online database (<https://www.aquariumtradedata.org/>). This tool was created to communicate the volume and diversity of marine fishes and/or invertebrates imported into the US over three complete years (2008, 2009, and 2011) and three partial years (2000, 2004, 2005). To create this tool, invoices pertaining to shipments of live marine fishes and invertebrates were scanned and analyzed for species name, species quantities, country of origin, port of entry, and city of import destination. Here we focus on the analysis of the later three years of data and also produce an estimate for the entirety of 2000, 2004, and 2005. The three-year aggregate totals (2008, 2009, 2011) indicate that just under 2,300 fish and 725 invertebrate species were imported into the US cumulatively, although just under 1,800 fish and 550 invertebrate species were traded annually. Overall, the total number of live marine animals decreased between 2008 and 2011. In 2008, 2009, and 2011, the total number of individual fish (8.2, 7.3, and 6.9 million individuals) and invertebrates (4.2, 3.7, and 3.6 million individuals) assessed by analyzing the invoice data are roughly 60% of the total volumes recorded through the Law Enforcement Management Information System (LEMIS) dataset. Using these complete years, we back-calculated the number of individuals of both fishes and invertebrates imported in 2000, 2004, and 2005. These estimates (9.3, 10.8, and 11.2 million individual fish per year) were consistent with the three years of complete data. We also use these data to understand the global trade in two species (Banggai cardinalfish, *Pterapogon kauderni*, and orange clownfish, *Amphiprion ocellaris* / *percula*) recently considered for Endangered Species Act listing. [Aquariumtradedata.org](https://www.aquariumtradedata.org/) can help create more effective management plans for the traded species, and ideally could be implemented at key trade ports to better assess the global trade of aquatic wildlife.